International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 4, Aug 2019, 839-848

TRANS STELLAR
•Journal Publications •Research Consultancy

Original Article

AN INTEGRATION OF SMART GRIDS WITH DEMAND SIDE MANAGEMENT AND RENEWABLE ENERGY: A REVIEW

BHARTI KOUL[1], KANWARDEEP SINGH[1] & Y. S. BRAR[2]

[1]*Department of Electrical Engineering, GNDEC, Ludhiana, Punjab, India*

[2]*Department of Electrical Engineering, IKGPTU Kapurthalla, Punjab, India*

ABSTRACT

The scheduling and improvement of the intelligible smart grid (SG) system is a combined part of the revolutionary target of accomplishing the distributed energy generation and transmission. The progression based on the fossil generation to the smart and renewable systems involves incorporation of innovative procedures at the utility as well as consumer end. It is evident from the present scenario that requirement of customer's demand-side methods expanding at present, and also more prospects in this area are to be accomplished. This paper presents the integration of demand side management (DSM), demand response (DR) and renewable energy in SG systems. The existing literature on DR and DSM integration has been discussed by studying current and relevant publications of journals and conferences in this research area.

KEYWORDS: Smart Grid, Demand Response Demand Side Management & Renewable Energy

Received: May 18, 2018; **Accepted:** Jun 08, 2019; **Published:** Jul 11, 2019; **Paper Id.:** IJMPERDAUG201986

INTRODUCTION

SG transfers the bidirectional power between the electricity suppliers and customers with the help of computational proficiency to save energy, operation cost and be an ecologically favourable system. The significant factors responsible for a transaction from conventional system to today's bidirectional power market are larger electricity demand, use of several renewable energy sources, greater peak load demand and an old network arrangement. The SG is also responsible for increasing the communication and synchronization among different parties associated with this bidirectional communication accomplished for stretched transmission networks or confined distribution systems. Among the substantialfeatures of SG major one is to sanction bidirectional communication between the performers in the grid so as to optimize electricity usage, and involvement of users to enhance the efficiency of conventional power system. DR states to consumption of power from the regular consumption patterns in response to deviations in the price of electricity for a specific duration. DR can also be defined as the monetary motivations that are planned to convince lesser consumption of power when wholesale market prices are at peak or when system consistency is threatened [1,2].

The further organization of the paper includes sectionII whichpresents the impact of DR on monetary and power situations of SG, section III explains the literature review on influence of DR and SG, while section IV containsof acombination of DR in SG environment and finally section V concludes with several characteristics discussed in the paper.

Impact of Demand Response and Demand Side Management on Smart Grid

This section discusses an illustration to validate the effect of DR on power economic scenario of the SG. The various load curves of the power structure are arbitrarily varying with time and are set by the sequential load curves of the specific areas. Figure.1 shows the load patterns that have been considered for the daily load curve of a given region in this example.

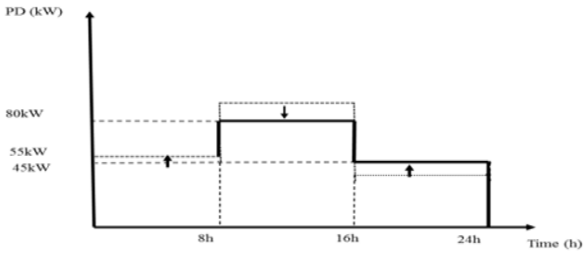

Figure 1: DemandCurve

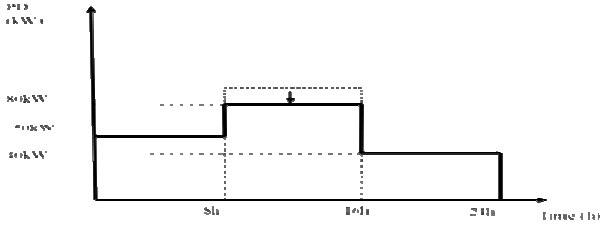

Figure 2: PRCurve

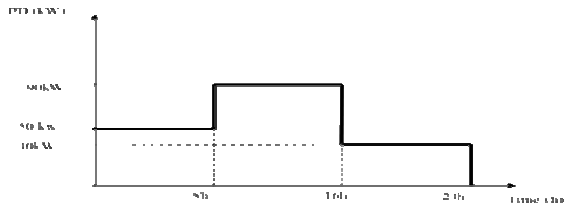

Figure 3: Price Responsive Demand Shifting Curve

Lagrangian multipliers of equality constraints (λ) that are the by-products of optimal power flow (OPF) solution are used to attain the pricing signals throughvarious load patterns.

Figure 2 and 3 shows the effect of DR that is studied in this case by considering price responsive (PR) and price responsive demand shifting (PRDS) of customers. The λ is set as Rs 4/KWh and Rs 6/KWh for peak hours and for off peak hours respectively. In this study firstly for the PR demand thecustomersparticipate to lessen the peak load and in case of PRDS, the users manage the load shifting to minimize the peak as well as the loss of energythrough off peak durations. Table 1 and 2 includes the load payments and energy consumed. The above analysis indicates that both the customers and energy suppliers are benefitted as consumers are profited by minimizing maximum load while the energy providers are profited by a reduced amount of cost. This simple and easy study shows that the DSM or demand response is very supportive in managing the peak duration price, minimizing the energy, load congestion management. The next section gives a detailed analysis of DR and renewable resources in SG.

Table 1: Load Profile

	Time Duration (hrs)	Base Value of PD (kW)	Peak Reduction (PR)	Peak Reduction Demand Shifting (PRDS)
Off -Peak	8	50	50	55
Peak	8	90	80	80
Off-Peak	8	40	40	45

Table 2: Load Payments and Energy Consumed

	Constant Price	Varying Price(Rs)	Total Energy used
Base case	(50*5*8)+(90*5*8)+(40*5*8) = 7200/-	(50*4*8)+(90*6*8)+(40*4*8) =7200/-	1440kWh
PR	(50*5*8)+(80*5*8)+(40*5*8) =6800/-	(50*4*8)+(80*6*8)+(40*4*8) =6720/	1360kWh
PRDS	(55*5*8)+(80*5*8)+(45*5*8) =7200/-	(55*4*8)+(80*6*8)+(45*4*8) =7040/-	1440kWh

Smart Grids and Demand Side Management with Renewable Energy

One of the recent and current areas of research is the study of DSM and its incorporation in SG. An SG is a strengthenedand efficient form of the conventionalpower system, with a reciprocateand control proficiencies, that encompasses of modified functions and applications which can work better which are the smart meters (SM) used for residential and industrial applications to equallyhelp the users and energy providers. The SMmarks a modified and efficient alteration which is able to link with the data supervision system positioned oninternet based system which is remotely located and to confirm a reliable and wireless switching system for switching on and off.

Lee *et al.* [3] have discussed a three layer system as: (i) a physical power layer, (ii) a data transport and control layer and (iii) an application layer. In reference [4] the authors have undertaken an advanced system for SG controlling which purposes at reducingthe chargesstrengthened for carrying out the distribution of energy to consumers. Theengagement of distributed generation (DG) and SG schemes of growing countries vigilant analysis are accompanied in order to realize the procedural and financialeffects of such enterprises. Various strategies are adopted with the help of administrative support like (EISA) act [5], (ARRA) act [6-8]. As the electrical structure is vastly capital-intensive and DR is one of the economic resources available to manage the system [9-14]. Gill *et al*. [15] have shown demand curve levelling and studied the problems of locational marginal pricing with the help of DSM and DR programs. Reference [16] has studied the bidding pool-based day-ahead electricity market by using PR and PRDS to manage the congestion management of the transmission network. Some of the research papers have taken bus voltage and line current as random variables by using stochastic optimization (SO) to minimize system losses [17-18].

Incorporation of Demand Side Management with Renewable Energy

Aninclusive review of someDR programs and renewable energy systemsdependent on the motivationsgiven to the users is discussed [19]. The SMs are also an easily accessible way to the price values and consumption of power in SGatmosphere andcan also they are able to contributein the process of demand management according to the choice by the help of DR. The integration of DR and DSM with renewable energy in smart grids is as shown in Figure 4.

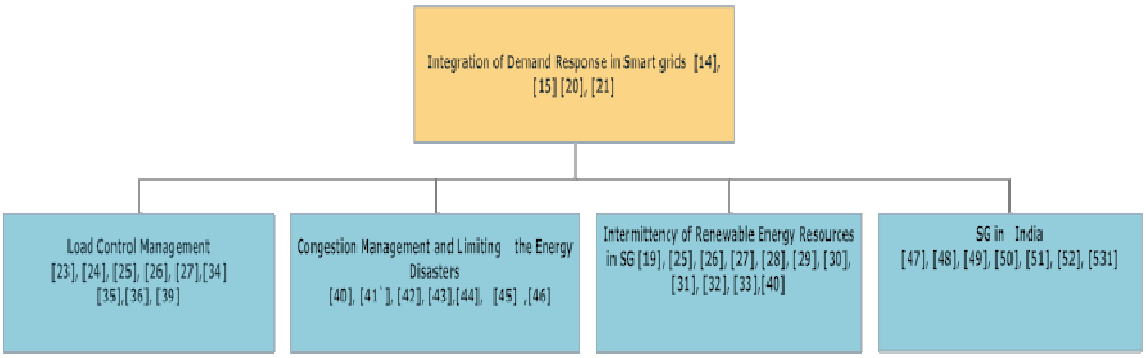

Figure 4: Incorporation of Demand Response in Smart Grids

Incorporation of DR in Management Load Profile

Inorder to cope up with sudden variations in both supply and demand levels the DR programs provide utility with definite load reduction ability. With the help of SM, wireless demand control and pricing based system on the hourly spot ratepooled with a time-of-day network tariff is discussed by Saele *et al.*[20-21] for a pilot study of DSM forresidential customers. In reference [22] the electricity expenses are diminished by incorporating the models with real-time- pricing (RTP) that can provide customers the chance to diminish the electricity expenses which vary for different periods during 24 hours. Authors in [23-24] have discussed thescheme of price elasticity based load control in which the management of demand is activated with necessity of electricity provider to decrease the demand.

An improved direct control genetic programming is proposed to improve the planning and rearranging the loads. A structurecorresponding to the search approach in artificial intelligence is employedfor findingthe convenient reschedulingmeasures. In a SG environment a conceptual framework is presented in [25] as a DR allowed 240V utilization observing-control division, that permits application of DSM programs for proposing an idea to a conceivable execution of significant DR techniques. A load forecasting problem for residential consumers has been framed [26-28] with the help of coupled restraint game where the result is controlled with different and incorporation of temporally-coupled limitations.

A motivation based organization/shifting of loads is considered [29-30] for both centralized and decentralized structures by using anoptimization and game theoretic approach. While on the other hand, inreference [31] a procedurecalled aggregate game handling is used for restoring theperformance of customersby proximal point procedure and cheat proof analysis [32-33]. Severalmethodsby means of game theory policies and programming study have been used in exhibiting the strategy for minimizing cost for the sake of buyers and maximizing the peak to average ratio for the utility [34-35]. A virtual power plant concept is proposed which comprises of gathering the capability of several distributed energy resources so as to make them more accessible and adaptablein allpower markets [36-38].

Implementation of DR Program and DSM in Managing Congestion Management (cm)

Many structural destruction and congestion in the system causessevere effects on power systems. For managing these effects various DR programs are implemented for preventing the energy crisis, CMmay also be treated as an optimization problem with a variety of variables. DSM approach isthe solutionfor such CM problems [39, 40]. If the value of load demand is greater than generation then to implement DR becomes proficient [41]. A key for CM is studied by authors in [42] developing a multi-objective algorithm to reduce rates/bills in the loads that are based on voltage.

References [43, 44] defined theimpact of capacityresistance in resolving the CM problem with the help of logicalmethodology for evaluating the impacts of price dependent demands on the congestion of transmission lines by disintegrating the LMs connected to theovercrowded lines to constitutive modules at marketplacestability. This shows the impact of trading policies and extreme demand of price-baseddemands on the overloading in power communicationnetwork. An inclusive study of CM is discussed by the authors of [45] which accomplished by allocating themethods and proceduresto different parts e.g. (i) Electricity market, (ii) conventional optimization methods, and (iii) CMmethods dependent on new techniques.

The authors of [46] have discussed Extra DR program (EDRP) among the DSM and DR techniquesfor meeting the transmissioncapabilityconstraintsto diminish theCM in transmission network. ASensitivity Index (SI) as discussed in [47] to simultaneouslycombine price and sensitivity to choose sharing demands for Demand shifting.

DR Programs in Moderating the Intermittency of Renewable Energy Resources (RES) IN SGS

Application of SG systems to improve the efficacy as well as saving of power and energy savings in many fields like in automotive industry (e.g.) electric vehicles (EV) is possible by the incorporation of DSM and DR programs. As SGs possess a bidirectional interchange of electrical power and information that leads to enable the incorporation of RES and EV. The combined system which involves grid power and energy from RER systems canperform as independent networks resulting in refining the quality of power and improving the reliability of the overall system thus leading to meet the supply demand ratio.

The incorporation of DR programs into SG deals for adjusting the load to increase existing electricity of the system. It is reflectedthe incorporation of smart grid with the DSM and DR canexpedite improvedportion of RES and to decreaserequirement of prevailing electricitybackup that depends upon on RES. Huge volumes RES with the grid [48-50] is extensivelybeen studied in the literature, howeversome [51-52] report the complicationsrelated topossibleinvolvement to the power industry [53]. Some corporations help to encourage incorporation of DR and DGin SG environment. Some noticeable corporations are American Recovery and Reinvestment Act (ARRA) Federal Energy Regulatory Commission (FERC) [54].

In order to report novel challenges in supply and transmission systems for wholesale spheres, Rahimi *et al*. [55] have deliberatedvariousaspects of distributed resourcesin SG systems for which concentratedthe focus on DSM programs, RTP and RES which givespossibleresolutionsfor facing the upcoming problems in distribution and transmission systems. On the same lines investigators have widely studied [56-59] about incorporation of RESs for an intelligent system known as SG system. This becomes perplexing by the intermittent characteristic owned by PV and wind sources [60].

CONCLUSIONS

- The incorporation and implementation of DR programs in the current power scenario is a substantial possibility that will lead the prevalent power system towards anadvanced and smart power structure. This is a way of managing the energy usage to enhanceexisting generation resources which provide a resolution to revise or modify electricity supply-demand ratio.
- The review has drawn incidenceof incorporation of DR techniques so that to make the current electrical power system as two way communication system. According to the studies the vibrant features of SG along with the DSM

and DR programs materialise to achieve the harmonizing of the entire supply-demand imbalance in the current electrical system.

- The state-of-art on DR and DSM program for managing the deficiency of power is discussed that supports to accomplish the shortage and to use the energy in smatter way which can lead to magnify theoverall proficiency of the entire power system.
- It is valuable to give emphasis to on new bidirectional infrastructure for self-healing grids, study of efficient power quality, and studying on the improved consistency of the prevailing electrical industry.

ACKNOWLEDGEMENTS

Bharti Koul is obliged to AICTE for QIP scheme to provide a chance to peruse PhD.

REFERENCES

1. *D. S. Kirschen. , (2003) Demand-side view of electricity markets". IEEE Trans. Power System.,vol. 8(2), pp.520–52.*
2. *C W. Gellings Then and now, (1996)The perspective of the man who coined the term 'DSM , Energy Policy; vol.24(4), pp.285–8.*
3. *J.Lee ,et.al. Smart Grid Solutions, Services, and Business Models Focused on Telco. In IEEE Network Operations and Management Symposium Workshops (NOMS Wksps)(pp. 323-326)*
4. *H .Aalami, et.al (2010)Demand response modeling considering Interruptible/Curtailable loads and capacity market programs, Applied Energy ,vol. 87(1), Energy Independence and Security Act (EISA). , www.oe.energy.gov/smartgrid.htm , 2007.*
5. *American Recovery and Reinvestment Act (ARRA). (2009) [Online]. Available: www.energy.gov/recovery and www.recovery.gov.*
6. *Canada's Action on Climate Change. [Online]. Available: www.climatechange.gc.ca , 2010.*
7. *European Commission - Europe [Online]. Available: ec.europa.eu/Europe 2020 , 2010.*
8. *S. Mocarquer, et. al (2009), Balance of Power, IEEE Power and Energy Magazine, vol. 7, pp. 26-35.*
9. *H. Rudnick, Public Policy and Energy (2009) [Guest Editorial], IEEE Power and Energy Magazine, vol. 7, pp. 12, 14, 16-17.*
10. *H. Rudnick, et.al (2008), A Delicate Balance in South America, IEEE Power and Energy Magazine, vol. 6, pp. 22-35.*
11. *R. Walawalkar, et. al (2010)Evolution and current status of demand response (DR) in electricity markets: insights from PJM and NYISO,. Energy; vol. 35(4).*
12. *M. Albadi, E. El-Saadany, (2008).A summary of demand response in electricity markets". Electric Power Systems Research vol.78(11).*
13. *S. Caron , G. Kesidis, (2010). Incentive-based Energy Consumption Scheduling Algorithms for the Smart Grid, IEEE trans., 978-1-4244-6511-8/10.*
14. *C. Gill , Y S Brar, K. Singh , (2012) Incentive Based Demand Response Program : An Effective Way To Tackle Peaking Electricity Crisis, 25th , IEEE canadian conference on electrical and computer engineering (CCECE) .*
15. *K. Singhet.et al (2011), Influence of Price Responsive Demand Shifting Bidding on Congestion and LMP in Pool-Based Day-Ahead Electricity Markets, IEEE Transactions on Power Systems, vol. 26(2).*

16. *P. Chenet.al (2010), Stochastic Optimization of Wind Turbine Power Factor Using Stochastic Model of Wind Power, IEEE Transactions on Sustainable Energy DOI 10.1109/TSTE.2010.2044900.*
17. *S. John ,et.al A Survey on Demand Response Programs in Smart Grids: Pricing Methods and Optimization Algorithms" IEEE Communications Surveys and Tutorials.*
18. *S. Kakran, S. Chanana, (2018)Smart operations of smart grids integrated with distributed generation: A review" , Renewable and Sustainable Energy Reviews, vol 81 pp. 524–535.*
19. *D. Guo, et. al (2013) Decentralized control of aggregated loads for demand response," in Proc. Amer. Control Conf. (ACC), Washington, DC, USA, pp. 6601–6606.*
20. *H. Saele and O. S. Grande ,(2011) Demand Response from household customers: Experience from a pilot study in Norway, IEEE Trans. On Smart Grid, vol. 2(1), pp. 102-109.*
21. *P. Faria, et.al (2011), Demand response management in power systems using a particle swarm optimization approach, IEEE Intelligent Systems, vol . 99, pp. 1-9.*
22. *J. A. Shortet. al, (2007)Stabilization of grid frequency through dynamic demand control, IEEE Trans. on Power Syst., vol. 22(3), pp. 1284-1292.*
23. *L. Yao, et.al (2011). Scheduling of Direct Load Control Using Genetic Programming, International Journal of Innovative Computing, Information and Control, Vol. 7,5(A).*
24. *M. Pipattanasomporn, et.al ,(2012) Demand response implementation in a home area network: a conceptual hardware Architecture . In: Proc. innovative smart grid technologies; pp.1–8.*
25. *L. Thillainathan, et. al (2012) , Demand Side Management in Smart Grid Using Heuristic Optimization. IEEE Trans Smart Grid; vol 3(3), pp.1244–52.*
26. *Z. Zhu, et. al . (2012) An Integer Linear Programming Based Optimization for Home Demand Side Management in Smart Grid,. Innovative smart grid technologies (ISGT), IEEE PES.*
27. *Thakur, R. O. B. I. N., Suri, A. R. S., Kumar, S., & Kumar, A. N. I. L. (2013). A review of integrated renewable energy system in power generation. Int J Mech Prod Eng Res Technol, 3, 79-88.*
28. *D. Ruilong, (2014) Residential energy consumption scheduling: a coupled-constraint game approach. Smart Grid, IEEE Trans;vol. 5(3) ,pp:1340–50.*
29. *Chai Bo, (2014) Demand response management with multiple utility companies: a two-level game approach. Smart Grid, IEEE Trans; vol.5(2), pp: 22–31.*
30. *C. Yan , et.al (2014) , Incentive compatible demand response games for distributed load prediction in smart grids, APSIPA Trans Signal Inf Process;vol.3, pp.1–1 3.*
31. *A-H Mohsenian-Rad, (2010) A. Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid. IEEE Trans Smart Grid vol. 1(3), pp: 320–31.*
32. *Song Linqi, (2014).Demand side management in smart grids using a repeated game framework., IEEE J;vol. 32(7), pp: 1412–24.*
33. *Chen He, (2014) Autonomous demand side management based on energy consumption scheduling and instantaneous load billing: an aggregative game approach. Smart Grid, IEEE Trans;vol.5(4), pp: 1744–54.*

34. C. Bharathi et. al (2017), Genetic Algorithm Based Demand Side Management for Smart Grid, Wireless PersCommunDOI 10.1007/s11277-017-3959
35. S. Kakran, S. Chanana,(2018) Smart operations of smart grids integrated with distributed generation: A review , Renewable and Sustainable Energy Reviews, vol 81 pp. 524–535.
36. B. Shengrong, Yu F. Richard.,(2013) A game-theoretical scheme in the smart grid with demand side management: towards a smart cyber physical power infrastructure,. IEEE Trans EmergTopics Comput; vol.1(1), pp.22–32.
37. NekoueiEhsan, (2015). Game theoretic frameworks for demand response in electricity markets. Smart Grid, IEEE Trans, vol. 6(2), pp.748–58.
38. N. Ruiz, et. al (2009), A Direct Load Control Model for Virtual Power Plant Management, IEEE Transactions n Power Systems, vol. 24(2).
39. Z. Zhao, et. al (2015) Demand side management: A green way to power Beijing , J. Renewable Sustainable Energy, vol. 7, (041505).
40. S. Nojavan, et. al (2015) Optimal bidding strategy of electricity retailers using robust optimization approach considering time-of-use rate demand response programs under market price uncertainties , IET Gener., Transm. Distrib. 9, 328.
41. L. Goel, et. al (2007), A Framework to Implement Supply and Demand Side Contingency Management in Reliability Assessment of Restructured Power Systems, IEEE Trans. Power Syst. 22, 205.
42. S. S. Reddy, (2016) Multi-Objective based Congestion Management using Generation Rescheduling and Load Shedding, IEEE Trans. Power Syst. 32, 852.
43. E. Bompard, et. al (2000), The role of load demand elasticity in congestion management and pricing, IEEE Power Eng. Soc. Summer Meet. 4, pp.2229-2234.
44. S. M. Sadr and H. R. Mashhadi,(2015) Evaluation of price-sensitive loads' impacts on transmission network congestion using an analytical approach, IET Gener., Transm. Distrib. 9, 523.
45. www.researchgate.net/publication /322436207, April 2017.
46. E. Shayesteh, M.et al (2008.), Congestion Management Using Demand Response Programs in Power Market, IEEE Transactions.
47. J. Hazra, K Das, and D. P Seetharam, (2012). Smart Grid Congestion Management Through Demand Response, IEEE Smart Grid CommSymposium .
48. K. K. Sharma, B. Singh,(2012) Smart Grid - Approach to Improve the Existing Electrical Power System, International Journal of Computer Science and Communication Engineering Vol. 1 no. 1.
49. US Department of Energy, Benefits of Demand Response in Electricity Markets and Recommendations for Achieving them, Report to the United States Congress, February, 2006.
50. Kaur, J., Randhawa, V., & Mittal, R. Involvement of Rural Women in Utilization and Management of Renewable Natural Resources in Kandi Area of Punjab.
51. Mahmood,(2014). A New Scheme for Demand Side Management in Future Smart Grid Networks , 5th International Conference on Ambient Systems, Networks and Technologies (ANT-2014), Procedia Computer Science, vol. 32, pp.477 – 484.
52. Ipakchi and F. Albuyeh,,(2009) Grid of the future, IEEE Power EnergyMag., vol. 7, no. 2, pp. 52–62.

53. *M. Carriónet..al (2007) A stochastic programming approach to electric energy procurement for large consumers, IEEE Trans. Power Syst., vol. 22, no. 2, pp. 744–754.*
54. *Albadi MH, El-Saadany EF., (2007) Demand response in electricity markets: an overvie, Power Engineering Society General Meeting. Tampa, FL: Institute of Electrical and Electronics Engineers (IEEE); . pp. 1–5.*
55. *Federal Energy Regulatory Commission, FERC Order 719 [Online]. Available: http://www.ferc.gov/whats-new/comm-meet/2008/*
56. *F. Rahimi, A. Ipakchi, Demand response as a market resource under the smart grid paradigm,. IEEE Trans on Smart Grid. vol 1, no 1, pp-82-88.*
57. *R. Sioshansi, (May 2010) Evaluating the impacts of real-time pricing on the cost and value of wind generation, IEEE Trans. Power Syst., vol. 25, no. 2, pp. 741–748.*
58. *V. Vittal, (2010). The impact of renewable resources on the performance and reliability of the electricity grid, Bridge, vol. 40, no. 1, pp. 5–12.*
59. *S. M. Amin and B. F. Wollenberg, Toward a smart grid: Power delivery for the 21st century, IEEE Power Energy Mag., vol. 3, no. 5, pp. 34–41, Sep./Oct. 2005.*
60. *Vojdani, (2008). Smart integration,IEEE Power Energy Mag., vol. 6, no. 6, pp. 71–79.*
61. *Carlo Cecati, CostantinoCitro, PierluigiSiano, (2011). Combined Operations of Renewable Energy Systems and Responsive Demand in a Smart Grid , IEEE Transactions On Sustainable Energy, vol. 2, no. 4, october.*
62. *Sara, Z., & EL Habib, B. S. M. The Impact of Renewable Energy in Urban Planning Instruments the Case of the PDAU.*
63. *S. SofanaReka , V. Ramesh , (2015.). Smart Grid: A Survey On Demand Side Management And Demand Response Its Scope In Indian Power Sector , ARPN Journal of Engineering and Applied Sciences, vol.10(16).*